

Fundamental understanding of chemical processes in EUV lithography

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Motivation

- Get fundamental understanding
- Increase sensitivity and resolution of EUV resist

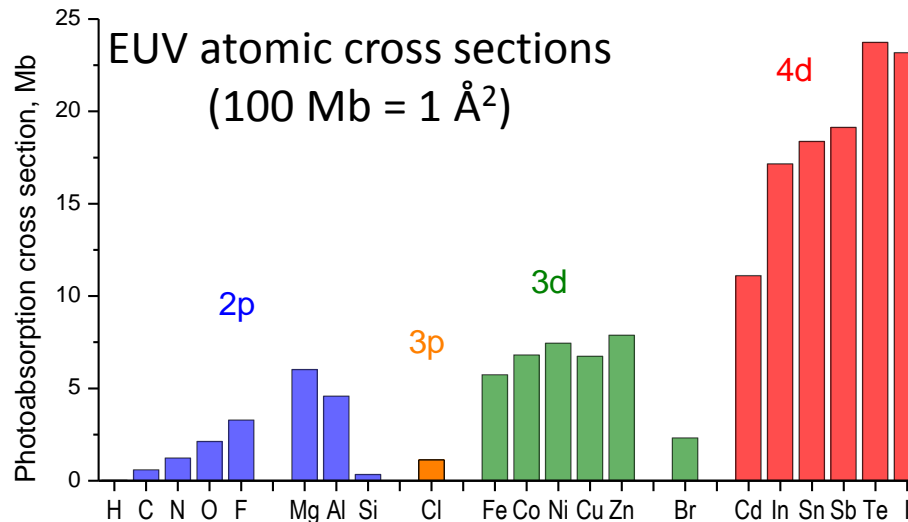
Targeted EUV dose for 7nm node

$$40 \text{ mJ/cm}^2 = 27 \text{ photons/nm}^2$$

GlobalFoundries

Table 1 Extreme Ultraviolet Absorption of Selected Materials

Material	Formula	Extreme Ultraviolet Absorption (50 nm film) (%)
Polypropylene	C_3H_6	11
Poly(methyl methacrylate)	$\text{C}_5\text{H}_8\text{O}_2$	24
Polyimide	$\text{C}_{22}\text{H}_{10}\text{N}_2\text{O}_5$	25
Teflon	C_2F_4	60
Hafnium oxide	HfO_2	30
Tin oxide	SnO_2	62



How to Get Fundamental Understanding?

Gas-phase
single molecule

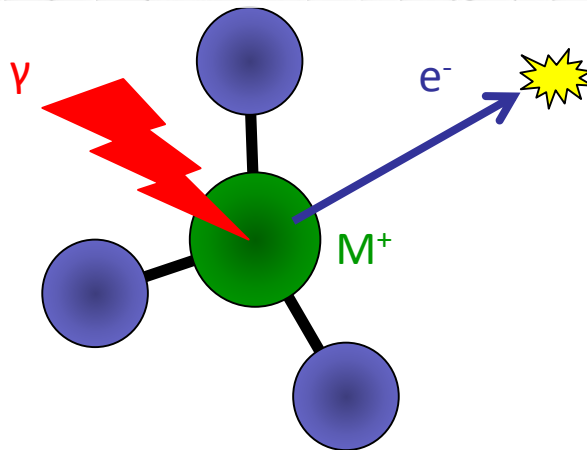


Condensed resist

Processes After EUV Photon Absorption

Step 1

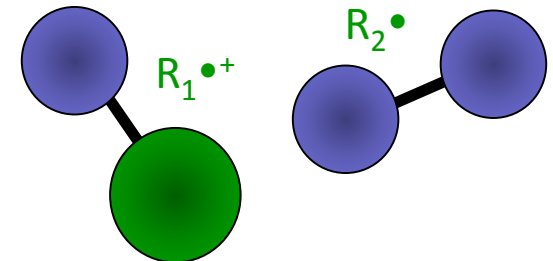
Photoionization



Step 3

Atomic Relaxation

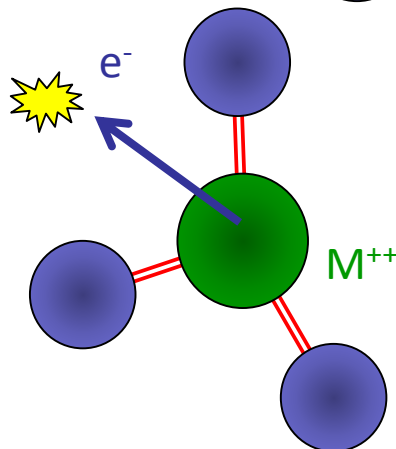
Fragmentation?



Step 2

Electronic
Relaxation

Auger process ?



How to Study?

Step 1 Photoionization



Step 2 Electronic Relaxation

Auger process ?



Photoelectron spectroscopy:

1. Electron kinetic energies
2. Electron yield

Step 3 Atomic Relaxation

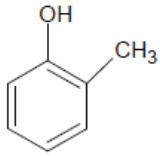
Fragmentation?



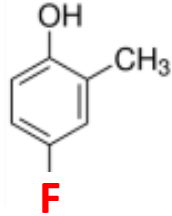
Mass spectrometry:

1. Fragmentation pattern after EUV photon absorption

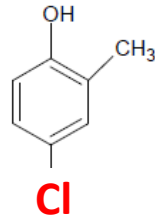
Samples



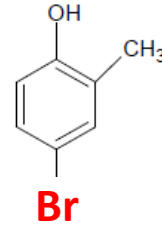
2-methylphenol



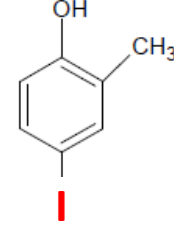
4-F-2-methylphenol



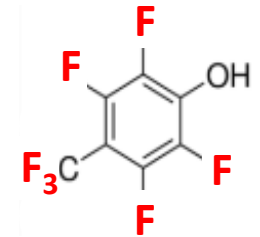
4-Cl-2-methylphenol



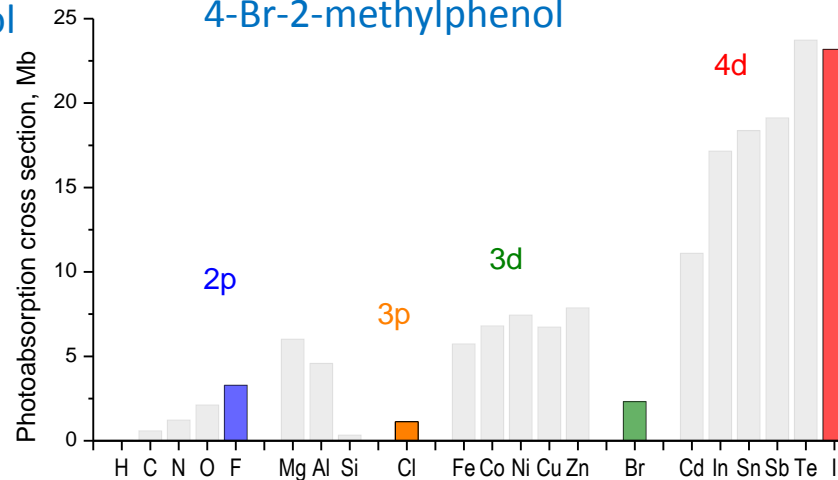
4-Br-2-methylphenol



4-I-2-methylphenol



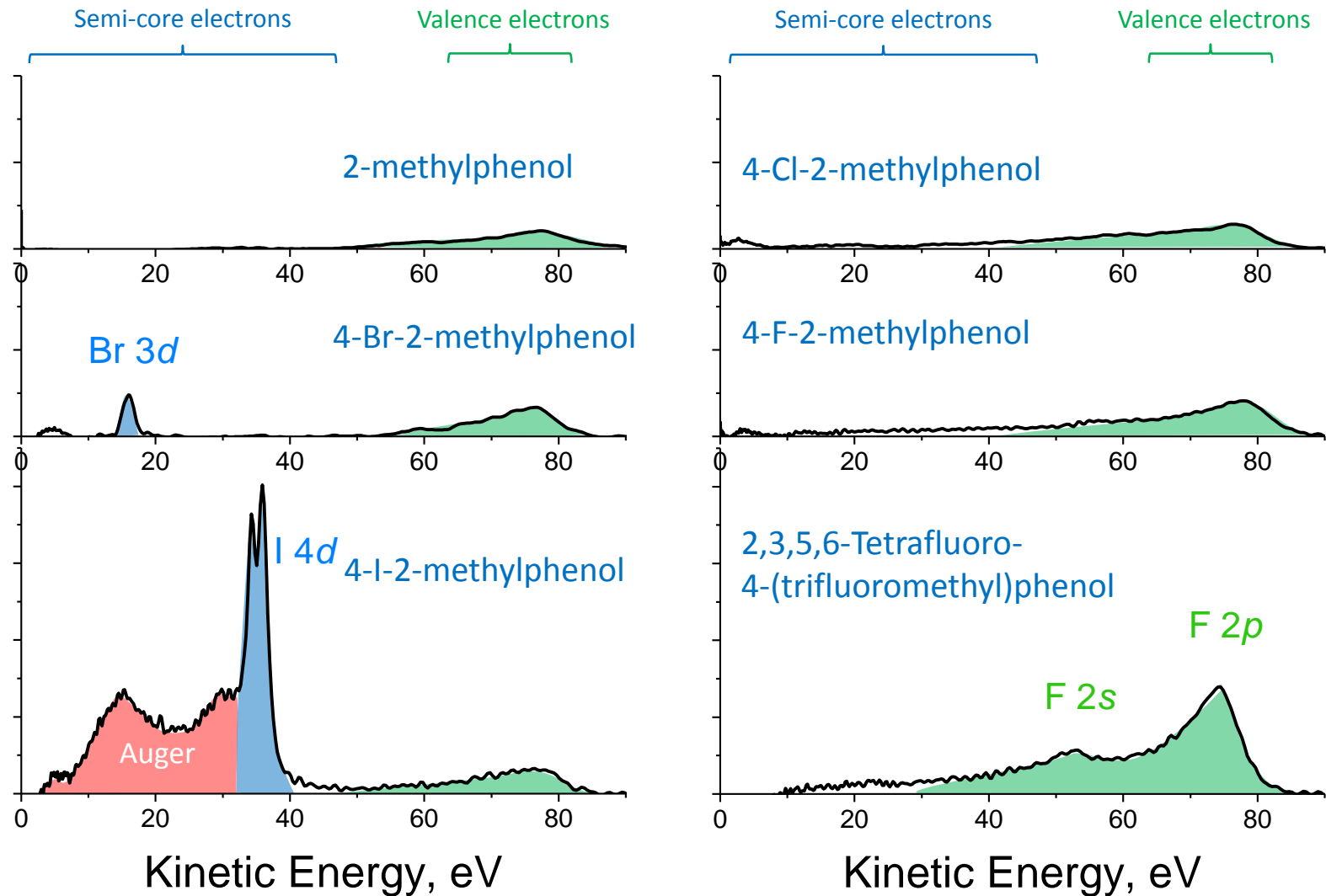
2,3,5,6-Tetrafluoro-4-(trifluoromethyl)phenol



Compound	Absorbed EUV photons (30nm), %
2-Methylphenol	11
4-F-2-Methylphenol	16
4-Cl-2-Methylphenol	11
4-Br-2-Methylphenol	13
4-I-2-Methylphenol	35
2,3,5,6-tetra fluoro-4-(trifluoromethyl)phenol	32

Photoelectron Spectroscopy

Step 1-2. Electron kinetic energies

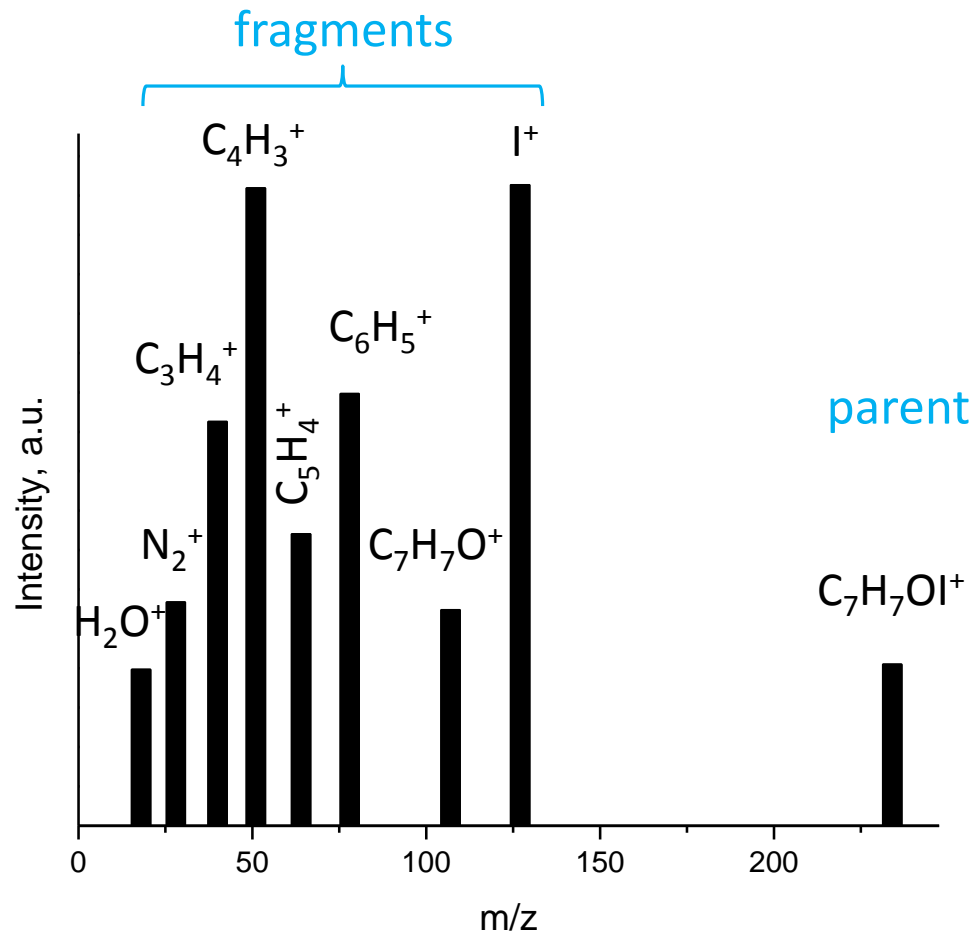


Tunable parameters:

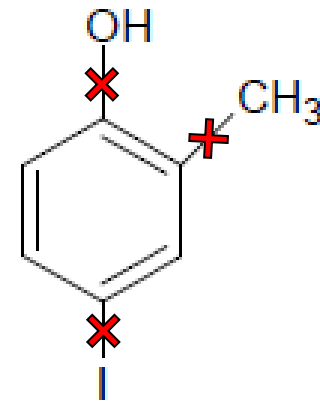
- Number of absorbed EUV photons
- Number of emitted e^-
- Energy of emitted e^-

Mass Spectrometry: Photons

Step 3. Atomic relaxation

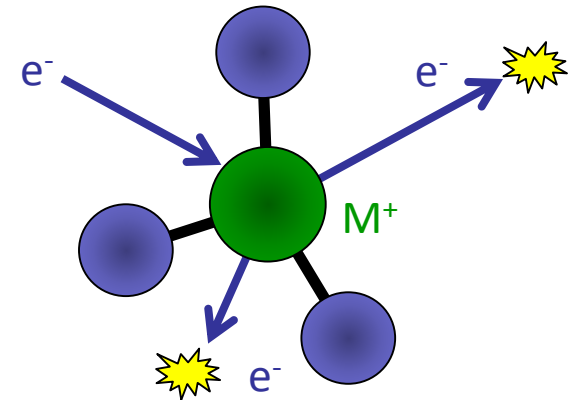


4-I-2-methylphenol



Condensed Resist?

- Photoabsorption, photoemission and Auger relaxation processes are almost unchanged
 - dielectric environment reduces binding energies ~ 4 eV
 - sharp lines are broadened
- Molecular fragmentation changes
 - fragments are trapped in polymer matrix, may recombine or generate secondary reactions...
- Inelastic electron scattering
 - electrons interact with molecules



Step 4 Inelastic Scattering



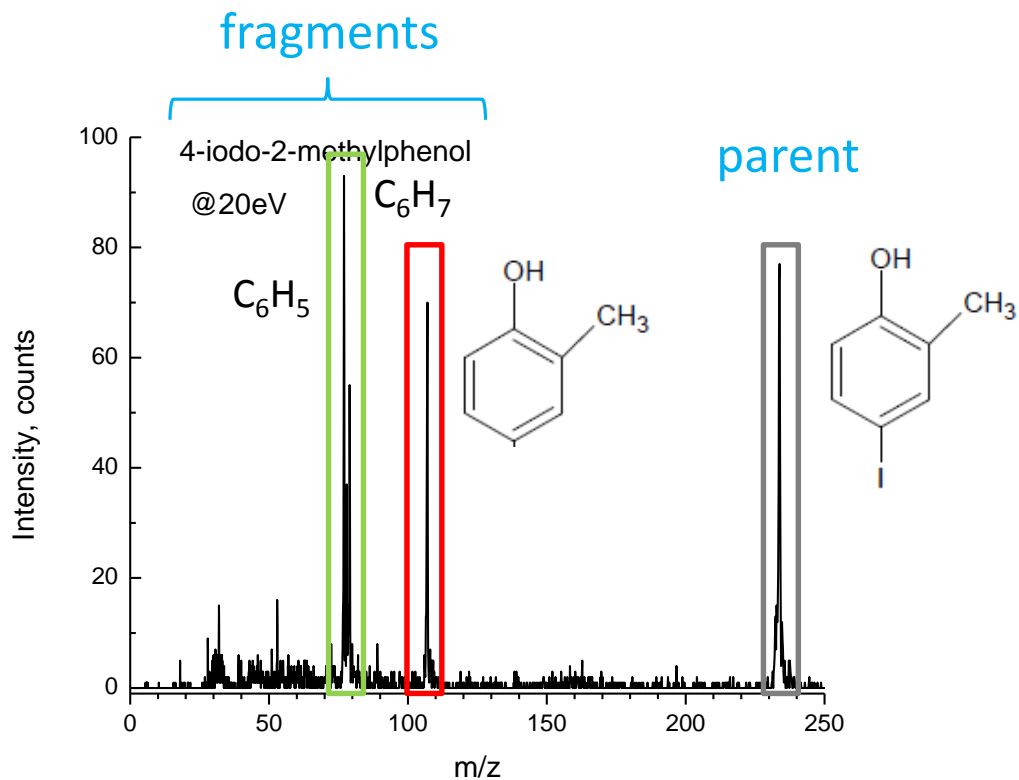
and more steps...

Mass spectrometry:

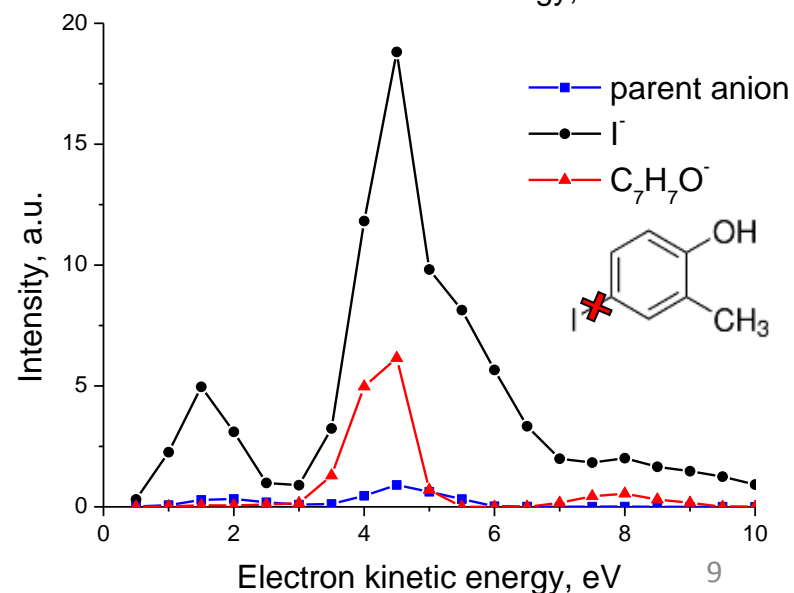
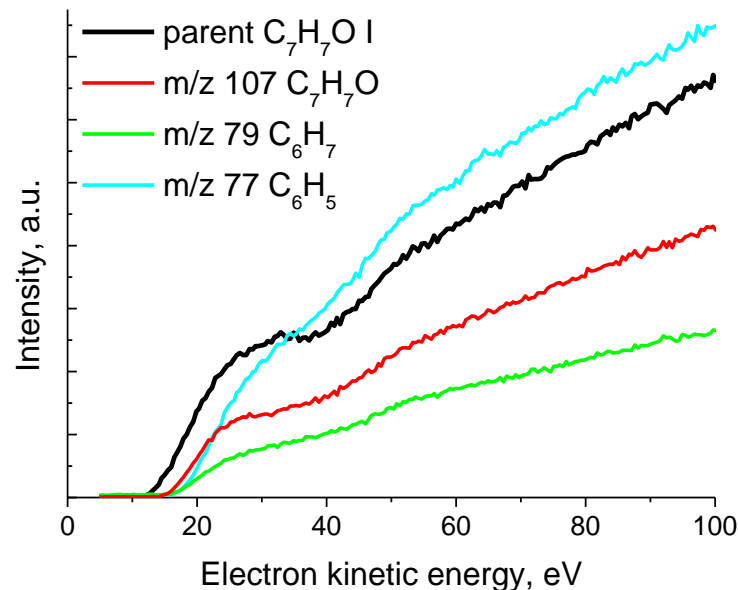
1. Fragmentation pattern after e^- collision

Mass Spectrometry: Electrons

Step 4. Inelastically scattered electrons



Low energy electrons:
dissociative electron attachment

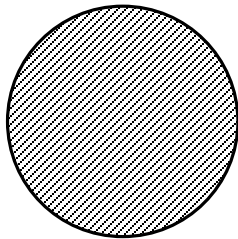


How to Study Condensed Resist

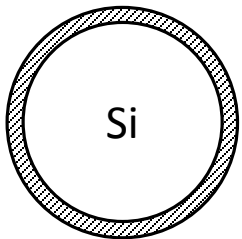
Gas-phase single molecule \Rightarrow Condensed resist

Nanoparticles of different morphology:

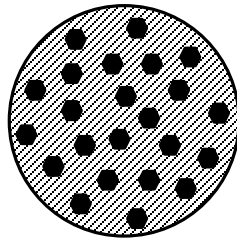
uniform



core-shell

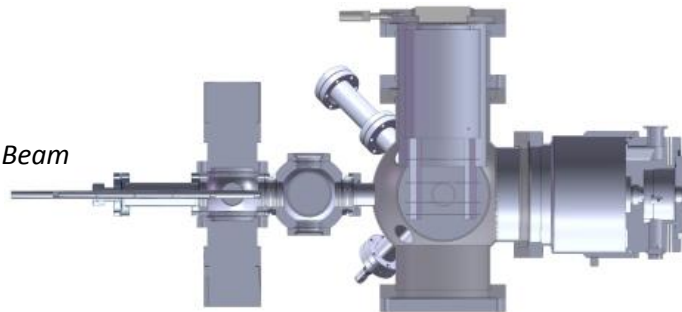


(sub)nanometer inclusions

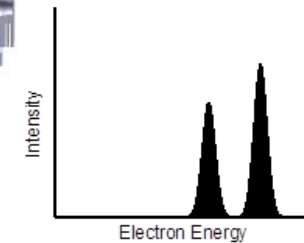
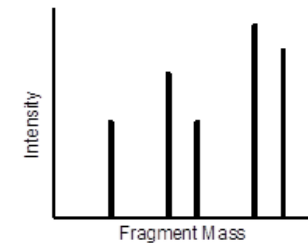


Diameter 50-500nm

Nanoparticle Beam



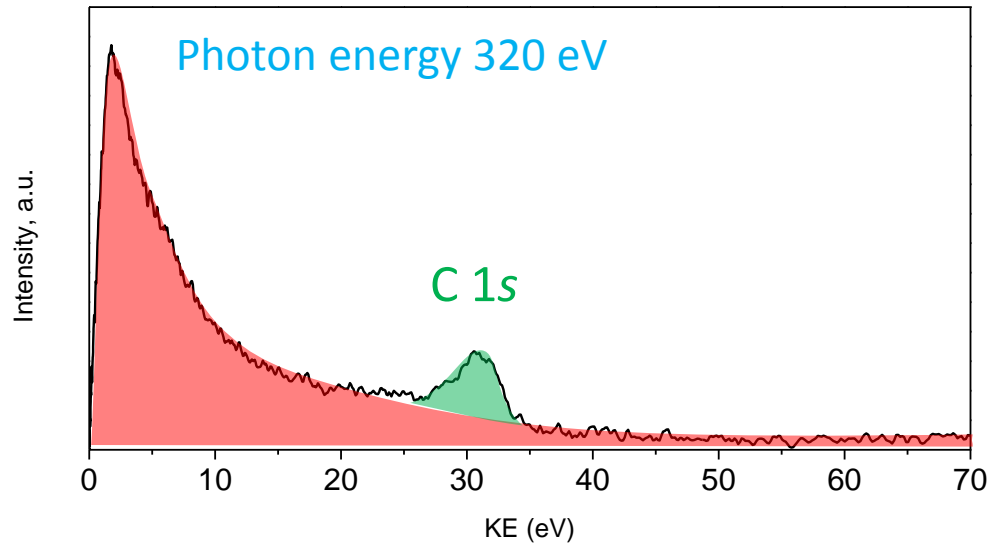
TOF-MS for chemical characterization of desorbed species



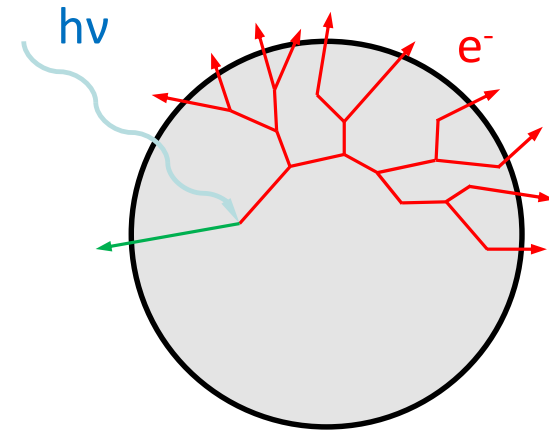
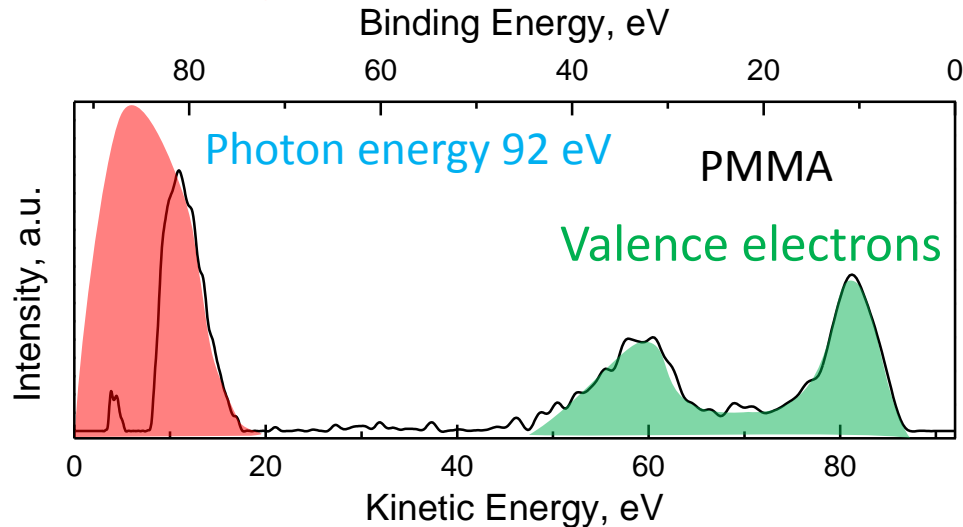
Velocity map imaging (VMI) for photoelectron energies and angular distributions

Photoelectron Spectra of Condensed Resist

E-beam resist: 4-Methyl-1-Acetoxycalixarene



Secondary electrons

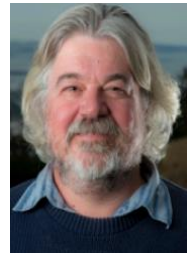


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Collaborative Team and Instrumentation is the National Lab Strength

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